A Review of Early Carboniferous Stratigraphy and Correlations in the northern Tamworth Belt, New South Wales

ARTHUR J. MORY

MORY, A. J. A review of Early Carboniferous stratigraphy and correlations in the *northern Tamworth Belt, New South Wales. Proc. Linn. Soc. N.S.W.* 105 (3). (1980) 1981: 213-236.

In reviewing the Early Carboniferous stratigraphy of the northern Tamworth Belt two stratigraphic units are amended. First, in the vicinity of Caroda, the Eungai Mudstone of McKelvey and White (1964) is regarded as a junior partial synonym of the Mandowa Mudstone with the rudite unit between, which they referred to as the Keepit Conglomerate, here recognized as the Kingsland Conglomerate Member (new name). Second, the Tangaratta Formation of White (1964a) is now included within the Goonoo Goonoo Mudstone of Crook (1961).

Correlations based on conodont faunas suggest the following modifications to the correlation offered by Jones and Roberts (1976) for the northern Tamworth Belt: (i) the Mandowa Mudstone ranges into the Carboniferous on the eastern limbs of the Werrie and Belvue Synclines, (ii) the break in sedimentation at the base of the Carboniferous (the Onus Creek Unconformity of White, 1964a) cannot be detected on the eastern limbs of the Werrie and Belvue Syclines, and (iii) the Luton and Namoi Formations have diachronous upper and lower contacts.

Arthur J. Mory, Geological Survey of Western Australia, 66 Adelaide Terrace, Perth, Australia 6000 (formerly *Department of Geology and Geophysics, University of Sydney)*; *manuscript received 4 November 1980, accepted in revised form 22 April 1981.*

INTRODUCTION

The Tamworth Belt (Harrington, 1974; Korsch, 1977), a NNW-trending structural unit on the western margin of the New England Fold Belt in northern New South Wales, contains rocks ranging in age from Cambrian to Permian (Leitch, 1974; Cawood, 1976). The belt is divided into two by Tertiary basalts forming the Liverpool Ranges and it is the Early Carboniferous succession in the northern half with which this paper is concerned (see Fig. 1).

The Early Carboniferous succession in the northern Tamworth Belt has been the subject of a number of papers since the 1850s; prior to the 1910s, however, this work was largely on fossil faunas from isolated localities with little mention of the relevant stratigraphy (e.g., W. B. Clarke, 1852-53; S. Stutchbury, 1853; L. G. de Koninck, 1876; E. F. Pittman, 1881; G. A. Stonier, 1871-95; R. Etheridge jun., 1887-1921; W. S. Dun, 1891-1920; and H. I. Jensen, 1907).

The first major survey of Carboniferous rocks in New England was that of W. N. Benson (1913-1920) as part of his study on the 'Great Serpentine Belt'. This survey was followed by those of S. W. Carey (1934, 1937) on the Werrie Basin and A. H. Voisey (1934-1942) on parts of the eastern half of the New England Fold Belt. Not until the 1950s did interest in the Carboniferous of the northern Tamworth Belt revive with the work of staff and students from the University of New England at Armidale, especially Engel, 1954; Williams, 1954; Voisey, 1958, 1959, 1964; Voisey and

Williams, 1964; Chappell, 1958, 1961a, 1961b; Crook, 1958; 1961, 1964; Manser, 1959, 1965, 1967, 1968; Campbell and Engel, 1963; Campbell, 1969; McKelvey and White, 1964; McKelvey, 1967, 1968, 1974; and White, 1964a, b, c, 1965, 1966. These investigations were largely lithostratigraphic in nature since most of the available palaeontological information was restricted to the western limbs of the Werrie and Belvue Synclines (Campbell and Engel, 1963; Campbell and McKellar, 1969; Jenkins, 1974; Roberts, 1975) giving little insight into along- and across-strike relationships of stratigraphic units.

This paper stems from a study of the Early Carboniferous conodont biostratigraphy of the northern Tamworth Belt (Mory, 1980), and unless otherwise stated, all conodonts mentioned herein from this region, have been recovered during that investigation. Further details of the conodont faunas are to be the subject of a number of joint papers on the Early Carboniferous conodont biostratigraphy of eastern Australia currently in preparation with Drs T. B. H. Jenkins and D. T. Crane. As Mory (1980) was primarily concerned with the time relations of the various Early Carboniferous lithostratigraphic units, the chronological aspect of these units is here emphasized. One unit, the Mandowa Mudstone (Chappell, 1961), was found to range in age across the Devonian/Carboniferous boundary and is thus a convenient starting point for a review of the Early Carboniferous stratigraphy of the northern Tamworth Belt.

MANDOWA MUDSTONE (Chappell, 1961)

Synonymy: ? Barraba Series, Benson, 1913a, p. 502.
? Barraba Mudstones, Benson, 1915b, p. 577; Voisey, 1958a, p. 209.
in part Manilla Group, Voisey and Williams, 1964, p. 67.
Mandowa Mudstone, Chappell, 1961b, p. 68; White, 1964a, b, c; Voisey, 1964; Manser, 1965; White, 1965; Moore and Roberts, 1976.
Mandowa Mudstone + Keepit Conglomerate + Eungai Mudstone, McKelvey and White, 1964; McKelvey, 1968.

Type Section: Whereas Chappell (1961b, p. 68) designated 'the provisional type section . . . on the western limb of the Klori Anticline immediately south of the Namoi River', he did not describe the nature of the upper boundary of the stratotype nor did he specify its position. Instead he indicated that the Kiah Limestone Member (= Borah Limestone Member herein) 'occurs within or slightly above the Mandowa Mudstone' in the type section. In view of the lenticular nature of the Borah Limestone and the difficulty of tracing a boundary within the poorly exposed associated mudstones at this level away from this section the definition of the type section of the Mandowa Mudstone here follows that of White (1964a, c) rather than Chappell (1961b). White (1964c) indicated that 'the provisional type section' extends approximately 1.5 km west of outcrop of the Borah Limestone Member to the base of the (?)Tulcumba Sandstone. As outcrop between the Borah Limestone and the (?)Tulcumba Sandstone is extremely poor a lectostratotype is desirable. Unfortunately, in the type area on the eastern limb of the Belvue Syncline outcrop is too poor to choose such a section; on the western limb a disconformity at the top of this unit, not detected to the east, makes the western sections similarly unsuitable. The nearest, well-exposed section known to the author through the Mandowa Mudstone is Slaty Gully near 'Burindi', 40 km to the north of Chappell's type section; as the Mandowa is there overlain by the Luton Formation, as opposed to the Tulcumba

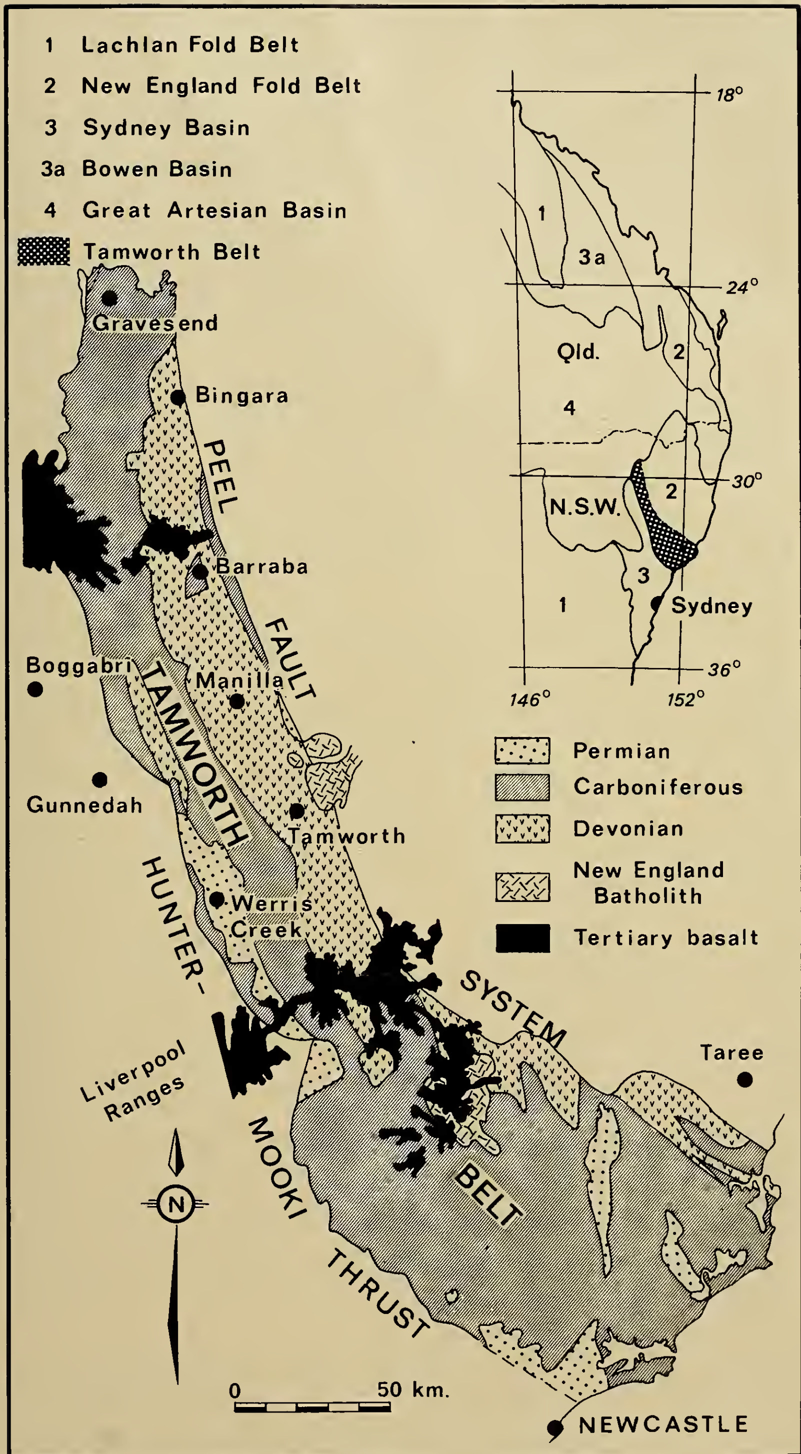

Fig. 1. Geological setting of the Tamworth Belt (after Pogson and Hitchins, 1973, Leitch, 1974).

Sandstone in the Namoi River section, the Slaty Gully section is here designated as a hypostratotype to supplement White's (1964a, c) type section.

Thickness: Approximately 650 m in the type section (White, 1964c) reaching a maximum thickness of over 900 m 85 km to the north near 'Luton'. Near Keepit Dam this unit reaches a maximum of nearly 300 m but in some sections the entire unit has been removed by erosion (Jenkins, 1969).

Lithologies: Massive mudstone beds up to 5 m thick alternating with thinly interbedded siltstones and mudstones which often contain minor sandstone bands generally less than 2 cm thick, and minor lithographic limestone and conglomerate.

Members: Two members within the Mandowa Mudstone are recognized herein; the Borah Limestone (Pickett, 1960) and the Kingsland Conglomerate, previously called the Keepit Conglomerate, in the vicinity of Caroda (McKelvey and White, 1964; McKelvey, 1968).

BORAH LIMESTONE MEMBER (Pickett, 1960)

Synonymy: Borah Limestone, Pickett, 1960, p. 237; Voisey and Williams, 1964; Voisey, 1964.
Kiah Limestone, Crook, 1961, p. 201; Chappell, 1961b, p. 68; White, 1964a, b, c; White, 1965; Manser, 1968.

Type Locality: On the south bank of Borah Creek at G.R. 489 089 (Tarpoly, 9036-IV-N, 2 inches/mile), on the eastern side of the 'Rangari'— Barraba road.

Thickness: 1 m at the type locality but may attain a thickness of up to 5 m.

Lithology: Blue/grey fine grained lithographic limestone often stylo-bedded and with ?authigenic feldspar crystals.

Although the Borah Limestone does not appear in every section of the Mandowa (and Goonoo Goonoo) Mudstones it is one of the most persistent units in the Tamworth Belt having been recognized as far south as 'Timor' near Murrurundi and as far north as 'Yagobie' near Gravesend, a distance of 260 km. The very fine-grained (lithographic) nature of the Borah Limestone, its lateral persistence, and its close association with the upper limit of *Leptophloem australe* (Crook, 1961; Gould, 1975), suggest that not only does it represent a long period of slow sedimentation but perhaps it may be considered as a close approximation to a time-rock unit. Within the Borah Limestone pseudomorphs after triclinic or monoclinic crystals of ?feldspar are locally abundant and have been interpreted as authigenic albite (White, 1965). The formation of authigenic feldspars has been reviewed recently by Kastner and Siever (1979); while these authors indicate that in carbonates albite is far more common than K-feldspar, the composition of the (?) feldspar in the Borah Limestone has not been determined.

Age: Pickett (1960) gave a Wocklumerian age for the limestone based on the supposed phylogenetic affinities of *Cymaclymenia borahensis* Pickett. Conodonts recovered by T. B. H. Jenkins from the Borah Limestone 5½ km north of 'Borah Vale' (at G. R. 423 195 Berrioye 8936-I-N, 2 inches/mile) include *Polygnathus communis communis* (2 specimens), *Bispathodus aculeatus aculeatus* (1) and

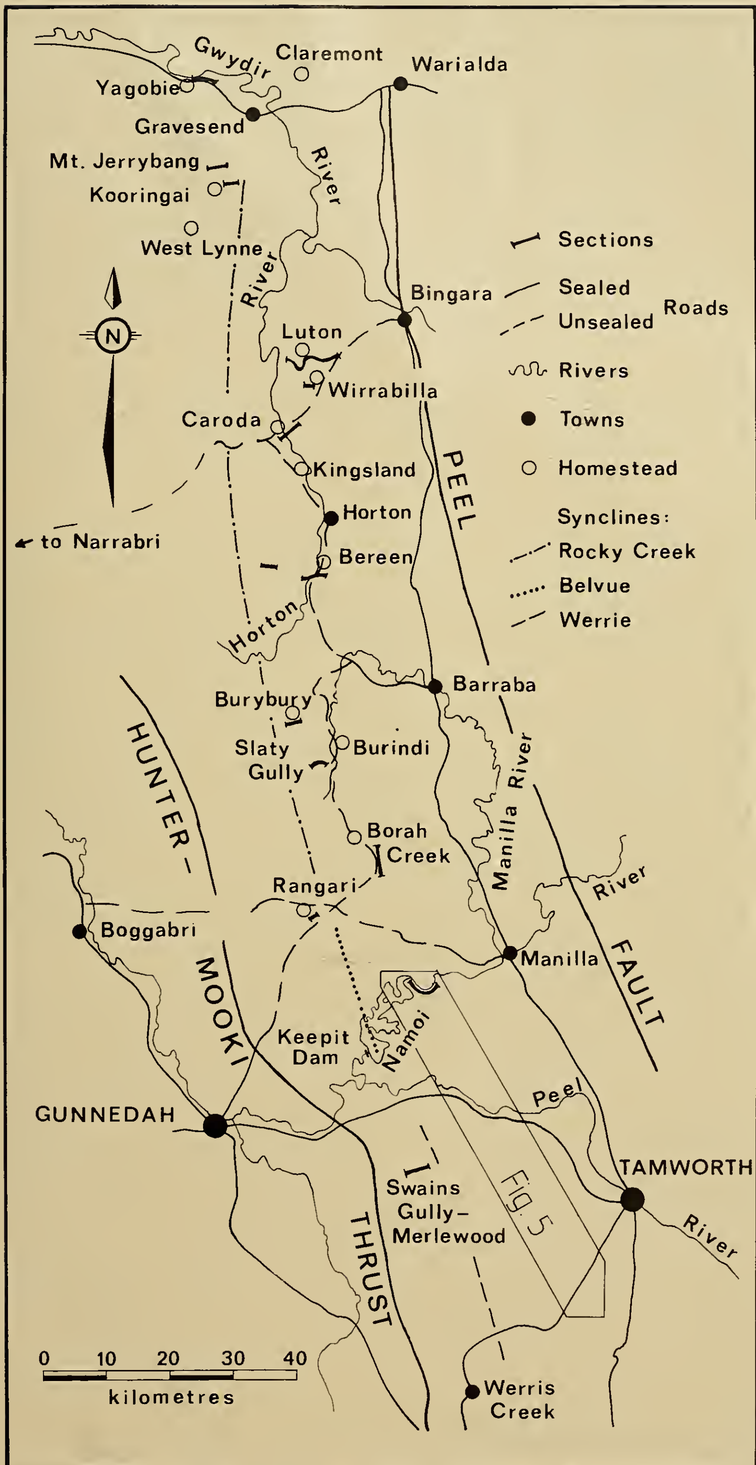

Fig. 2. Location of measured sections in the northern Tamworth Belt (to accompany Figs. 4 and 6).

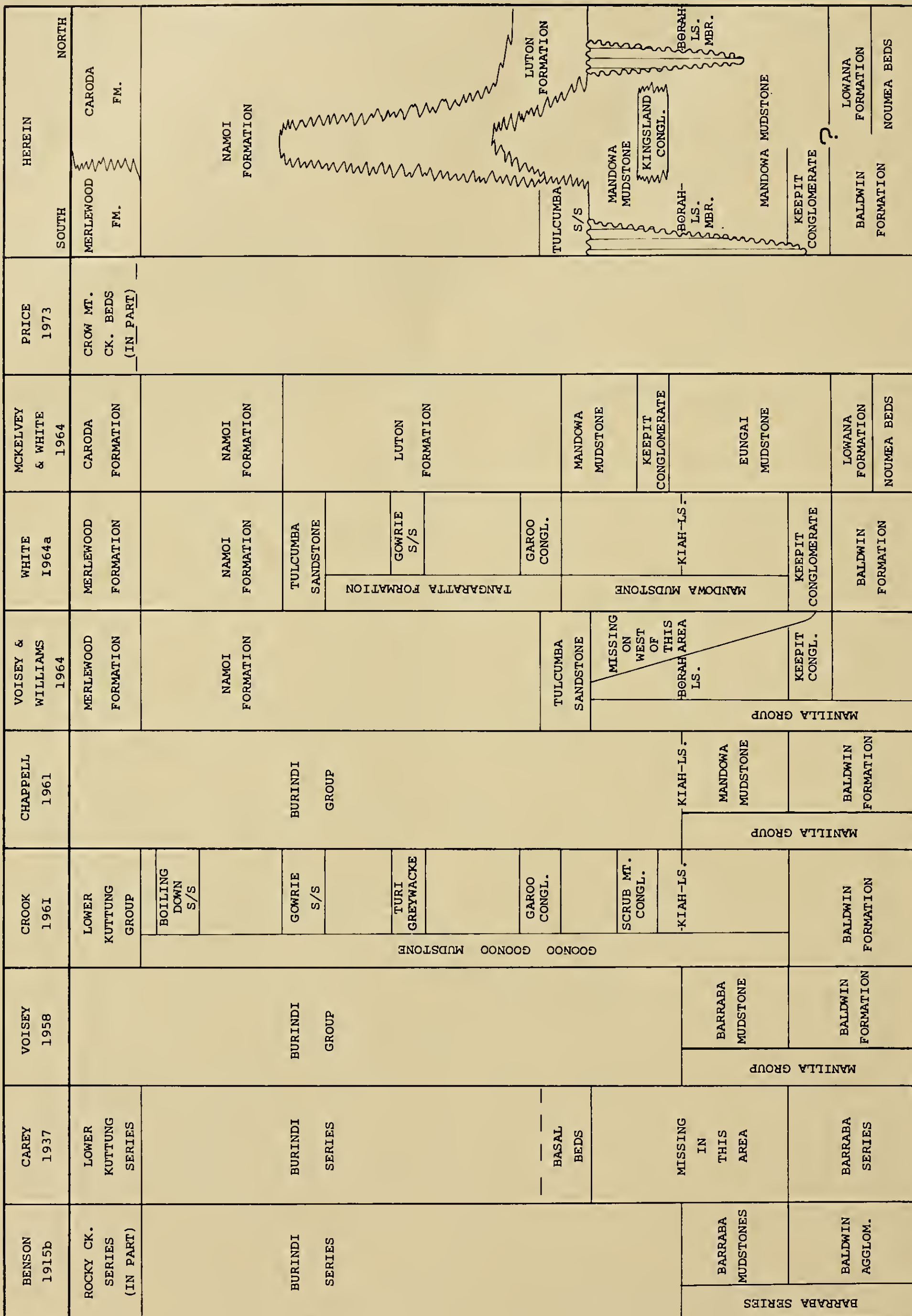

Fig. 3. Correlation of previous stratigraphic nomenclature.

Protognathodus meischneri (1). In the type section of the Mandowa Mudstone *Polygnathus vogesi* (2), and *Palmatolepis gracilis sigmoidalis* (4) were recovered 10 m above the limestone. These conodont species indicate an age within the *costatus* zone (or from the uppermost *Clymenia* Stufe into the *Wocklumeria* Stufe) for the Borah and thus support the age determination of Pickett (1960) based on a single new clymeniid species.

KINGSLAND CONGLOMERATE MEMBER (new name)

Synonymy: Keepit Conglomerate, McKelvey and White, 1964; Russell, 1979, 1980 (in part).

Derivation: After Kingsland Homestead 2 km north of the type section.

Type Section; Road cutting on the Upper Horton-Narrabri road at G.R. 345 766 Eulowrie, 8937-I-N, 2 inches/mile, 1 km NW of the bridge over Noogera Creek.

Thickness: 40 m in the type section, reaching 60 m near 'Wirrabilla', 10 km to the northeast.

Lithologies: Orthoconglomerate, sandstone, siltstone, mudstone and pebbly mudstone overlying massive mudstone with an abrupt or gradational lower contact. The upper contact is at the highest coarse sandstone, conglomerate or pebbly mudstone which is overlain conformably by thinly-bedded mudstones and siltstones with minor sandstone bands.

Age: Siphonodella duplicata, an early Tournaisian conodont species has been recovered from a limestone boulder 6.5 m below the top of this unit in the type section and also 30 m above its top at 'Wirrabilla' 10 km to the northeast. Fragments of *Siphonodella* sp. have also been recovered from a calcareous concretion 20 cm below this unit 3 km southwest of its type section on the southern side of the Horton road. The genus is restricted to the Carboniferous and its presence indicates that the erosional contact at the base of the Kingsland Conglomerate is not the result of a significant break in sedimentation.

Discussion: Previously this member had been identified as the Keepit Conglomerate (McKelvey and White, 1964; McKelvey, 1968) between 'Luton' and 'Bereen', presumably because of its stratigraphic position below a thick mudstone/siltstone sequence (the Mandowa Mudstone), itself below the Luton Formation. However the thick sequence of mudstone and siltstone below this member (the Eungai Mudstone of McKelvey and White, 1964) is not developed in the vicinity of Klori Trig, the type section of the Keepit Conglomerate; there the Keepit Conglomerate overlies strata dominated by argillites but also with arenites, greywackes and conglomerates (the Baldwin Formation). In view of the difficulty in distinguishing the Eungai Mudstone from the Mandowa Mudstone on lithological criteria, and the lack of outcrop of the Keepit Conglomerate between 'Burindi' and the vicinity of 'Kingsland' (a distance of 47 km), it is felt that it is necessary to place the Eungai Mudstone into synonymy with the Mandowa Mudstone and to rename the Carboniferous conglomerate.

Age and Faunas of the Mandowa Mudstone:

The age of the base of the Mandowa Mudstone has so far only been determined in two localities:

1. A thin conglomerate 6 km north of Keepit Dam has yielded the clymeniids

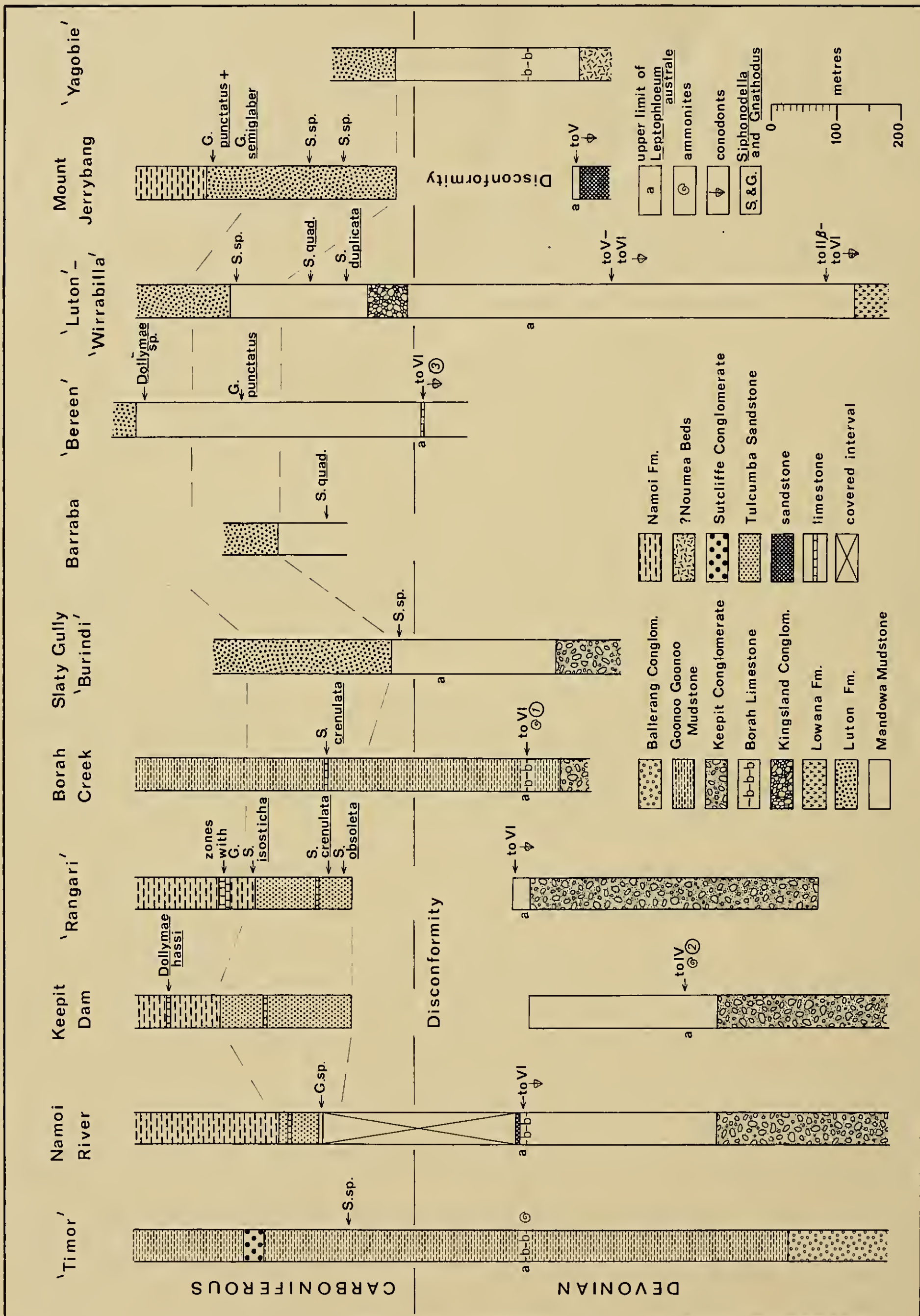

Fig. 4. Correlation of sections spanning the Devonian/Carboniferous boundary in the northern Tamworth Belt. The Timor section is situated 5 km north of the type section of the Goonoo Goonoo Mudstone. Ages indicated by circled numbers are from:
1. Pickett, 1960.
2. Jenkins, 1969.
3. Philip and Jackson, 1970.

?Rectoclymenia, Platyclymenia, and *Genuclymenia* indicating the *Platyclymenia* Stufe of the Famennian stage (toIV, Jenkins, 1969).

2. A decalcified concretion 3 m above the base of the Mandowa at Mount Jerrybang has yielded the conodonts *Polygnathus marginatus* or *praehassi* (1 specimen), *Palmatolepis ?perlobata helmsi* (10), *Palmatolepis gracilis sigmoidalis* (10) and *Drepanodus* sp. (6). This fauna indicates an age from the upper *styriacus* to lower *costatus* conodont zones, i.e. the *Clymenia* Stufe (toV).

In sections where the unit overlying the Mandowa Mudstone rests on a significant erosion surface the youngest faunas in the Mandowa are Famennian (Upper Devonian). In sections where the overlying unit shows a conformable relationship or a minor disconformity is present and the age of the top of the Mandowa can be determined it appears to fall in the Early Carboniferous (see Fig. 4). Unfortunately it is difficult to resolve just how diachronous the upper depositional limit of the Mandowa is, as very few localities yielded faunas from which precise ages can be determined. However at 'Luton' and Slaty Gully conodonts from the zones with *Siphonodella* (Tn1-Tn2) were recovered from this level whereas at 'Bereen' *Dollymae hassi* suggests the presence of the zones with *Gnathodus* (Tn3) at this level.

An important fossil in the Mandowa Mudstone (and its partial correlative, the Goonoo Goonoo Mudstone) is the lycopod *Leptophloem australe.* This fossil is considered not to range to beyond the Devonian in sediments in the New England Fold Belt (Gould, 1975). The few conodont occurrences associated with the lycopod and stratigraphically higher (summarized in Fig. 4), are in agreement with this age limit.

General and Historical Comments:

Between the Peel River and 'Burindi' the Mandowa Mudstone conformably overlies the Keepit Conglomerate. North of 'Bereen' Gap it conformably overlies the Lowana Formation and between Mount Jerrybang and 'Yagobie' the ?Noumea beds (see Fig. 4). Units overlying the Mandowa Mudstone may show a conformable or disconformable relationship. Between 'Merlewood' and 'Rangari' the Tulcumba Sandstone shows a persistently disconformable relationship with the underlying units; in some places the Mandowa Mudstone is missing entirely presumably due to erosion (Jenkins, 1969; White, 1964a, b, c). White (1964a, p. 212) called this break in sedimentation the Onus Creek Unconformity after the creek section of that name south of the Peel River on the eastern limb of the Werrie Syncline; remapping of that area (see Fig. 5), however, suggests that a break in sedimentation can only be recognized on the western limb of the syncline.

At Mount Jerrybang the Mandowa Mudstone, here only 10 m thick, is abruptly overlain by coarse sands of the Carboniferous Luton Formation. The age of the base of the Mandowa Mudstone at this locality (toV) and the disconformable nature of the contact with the overlying Luton show similarities with the Tulcumba/Mandowa contact between Swains Gully and 'Rangari'. These similarities suggest that the break in sedimentation is a continuous feature on the western limb of the Rocky Creek Syncline from 'Rangari' to Mount Jerrybang in spite of the lack of outcrop of rocks of this age between the latter two sections. In all other sections (on the eastern limbs of the Rocky Creek, Belvue and Werrie Synclines) the overlying Tulcumba Sandstone or Luton Formation rests conformably on the Mandowa Mudstone.

W. N. Benson (1913a, p. 502), who first mapped the Devonian and Carboni-

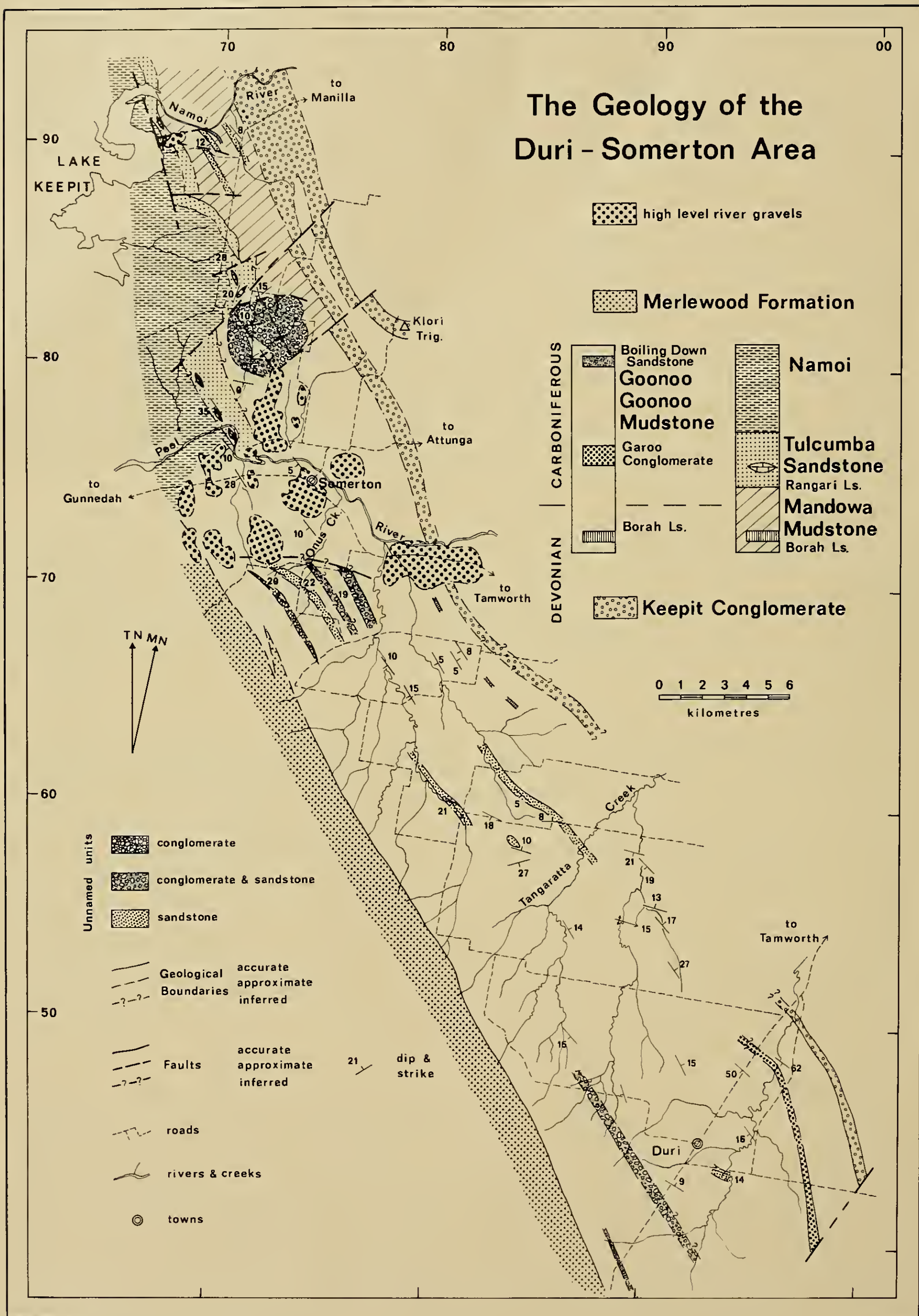

Fig. 5. Geology of the Duri-Somerton area.

ferous rocks north of the Liverpool Ranges, initially used the name Barraba Series to describe the sequence of 'banded shales and mudstones . . . Interbedded with . . . acid or intermediate tuff, . . . conglomerate, . . . tuffaceous agglomerate . . . and lenticles of blue argillaceous limestone'. He later (Benson, 1915b) used the term Barraba Mudstones interchangeably with Barraba Beds and Barraba Shales to mean the same as the Barraba Series of Benson (1913a). As no type section was specified for the Barraba Mudstones it is impossible to determine exactly how this unit correlates with modern subdivisions of the sequence.

Chappell (1961b, p. 68) proposed the Mandowa Mudstone to replace the Barraba Mudstones due to the number of meanings this term has assumed in the past'. However, he did not describe the nature of the upper contact in his type section implying that this boundary was recognized using the criteria employed since Benson (1913a) first defined the Barraba Series. Benson (1913a, p. 502) had said 'Indeed the distinction between the Barraba Series and the [overlying] Burindi Series, lies largely in the absence of *L. australe* (and radiolaria) from the latter'. He later (Benson, 1917a, p. 269) said *'It may be, therefore, that the true base of the Carboniferous System lies at some unrecognisable horizon in the Barraba mudstone. For the purpose of mapping, however, the base of the Burindi beds is the lowest recognisable horizon in the Carboniferous that can be traced'.* These statements suggest that the Barraba/Burindi contact was recognized at different stratigraphic levels in different areas and that the distinction between the two was often palaeontological rather than lithological. For the latter reason Crook (1961) working south of Tamworth grouped the Barraba Mudstones and Burindi Series into one unit, the Goonoo Goonoo Mudstone. As a general rule however the Devonian of the Mandowa Mudstone may be lithologically distinguished from the Carboniferous; the former is characterized by flaggy, thin bedded dark mudstones, siltstones and sandstones whereas the latter possesses massive mudstones and siltstones typically with little sandstone.

GOONOO GOONOO MUDSTONE (Crook, 1961)

Synonymy: Burindi Series + ? Barraba Series, Benson, 1913a, p. 502-3.
? Nundle Series, Benson, 1913b, p. 581; Benson, 1918a, p. 340.
Burindi Series + ? Barraba Mudstones, Benson, 1915b, p. 577; Carey, 1937.
Goonoo Goonoo Mudstone, Crook, 1961, p. 197; Roberts and Oversby, 1974, p. 10.
Namoi Formation + Tulcumba Sandstone + Tangaratta Formation + Mandowa Mudstone, (south of the Peel River on the eastern limb of the Werrie Syncline only), White, 1964a, b, c.
Licount Mudstone + Sutcliffe Conglomerate + Glenlawn Mudstone + Dancing Dicks Conglomerate + Martindale Mudstone, Manser, 1968.

Type Section: Timor Creek and its tributaries from G. R. 184 882 down to Timor Creek and then downstream to the junction with Deep Creek, up Deep Creek to G.R. 133 859 — Isis River, 9137-IV-N, 1:25,000, (Crook, 1961; modified after Manser, 1968).

Thickness: Approximately 2,000 m in the type section (estimate from Manser, 1968).

Lithologies: Olive-green to olive-brown mudstones, frequently with silty bands and small argillaceous limestone lenses; numerous labile arenite and conglomerate units, and one thin bed of lithographic limestone are contained within the mudstones (Crook, 1961, pp. 196-7).

Members: Crook (1961) recognized a number of 'sheet-like but ultimately lenticular' arenite and conglomerate members. In the western region of the area he mapped north of the Liverpool Ranges six members were recognized: the Kiah Limestone (= Borah Limestone herein), Scrub Mountain Conglomerate, Garoo Conglomerate, Turi Greywacke, Gowrie Sandstone and Boiling Down Sandstone (in ascending order). The eastern region is not discussed herein.

Manser (1968) subdivided the type section of the Goonoo Goonoo Mudstone into five formations based on the presence of two conglomerate horizons within the mudstone/siltstone sequence. Since both conglomerates are lenticular and sections exist with no lithological change between mudstone units, doubt as to the validity of the Martindale, Glenlawn and Licount Mudstones was expressed by Roberts and Oversby (1974, p. 11). It is suggested here that these names be regarded as junior partial synonyms of the Goonoo Goonoo Mudstone. The names of the two conglomerate units, the Dancing Dicks and Sutcliffe Conglomerates could, however. be retained for members within the Goonoo Goonoo Mudstone.

Discussion: White (1964a, b, c) in an adjacent area to the north of Crook (1961) recognized the Garoo Conglomerate Member and the Gowrie Sandstone Member of Crook (1961) but placed them within the Tangaratta Formation. In view of the exceptionally poor outcrop in Tangaratta Creek, the provisional type section of this unit (5 m of outcrop over the 6.5 km shown as Tangaratta Formation by White, 1964a, b) a lectostratotype needs to be selected. However, due to the sparse and impersistent nature of outcrop within the entire area shown as Tangaratta Formation by White (1964a, b, c) an accurate determination of the lithological character of this unit cannot be achieved, nor can lateral continuity of members be demonstrated (see Fig. 5). Thus the Tangaratta Formation should be regarded as a junior partial synonym of the Goonoo Goonoo Mudstone.

White (1966, pp. 212-3) also referred to the Tangaratta Formation a sequence of mudstones with three thin conglomerate, pebbly mudstone and sandstone members with erosional basal contacts 6 km northeast of 'Rangari' in Conglomerate Creek, a tributary of Rangira Creek. However, as the stratigraphically lowest conglomerate member lenses out 7 km to the north near 'Borah Vale' (Ian Wakely, 1978, pers. comm.) and the underlying mudstones cannot be distinguished from those above, this section is tentatively referred to the Goonoo Goonoo Mudstone. North of 'Borah Vale' the middle conglomerate has been traced along strike to the base of the Caroda Formation (Ian Wakely, 1978, pers. comm.). The overlying, poorly-exposed, mudstones are here thought to be time equivalents of the lower part of the Caroda Formation.

Age: Within the Goonoo Goonoo Mudstone fossils are rare except at the top of the unit in the Winton Limestone Member (White, 1964a). Conodonts from this limestone belong to the *S. anchoralis* Zone indicating a horizon high in the Tournaisian. The base of the Goonoo Goonoo Mudstone is latest Devonian based on the faunas of the included Borah Limestone.

Conodonts recovered from the base of the sandstone ridge on Priors Hill (G. R. 550 735 Winton, 9035-IV-N, 2 inches/mile) (shown as Garoo Conglomerate at the base of the Tangaratta Formation by White, 1964a, b) include *Gnathodus punctatus* and *Siphonodella* sp. This fauna indicates that this level is at least partly equivalent to the Tulcumba Sandstone at 'Carrol Gap' and 'Rangari' and the base of the Luton Formation in its type section (see Fig. 3). Further work is necessary to determine whether the Goonoo Goonoo Mudstone between 'Rangari' and 'Borah Vale' (best exposed in Conglomerate Creek) ranges into the Visean.

TULCUMBA SANDSTONE (Voisey and Williams, 1964)

Synonymy: Burindi Series, (in part), Lloyd, 1933, p. 31.
Basal beds of the Burindi series, Carey, 1937.
Tulcumba Sandstone, Campbell and Engel, 1963; Voisey and Williams, 1964, p. 68; White, 1964a, b, c (in part); Voisey, 1964, Manser, 1965; Jenkins, 1969; Roberts, 1975; Moore and Roberts, 1976.

Type Section: Swains Gully near 31°01.5′ S 150°28.5′ E, designated by Voisey and Williams (1964).

Thickness: 230 m in the type section thinning to 140 m at 'Rangari'. Overlying the type section of the Mandowa Mudstone is a unit consisting of approximately 60 m of thinly bedded siltstone with rare sandstone and limestone, questionably assigned to the Tulcumba Sandstone (see Fig. 5).

Lithologies: Coarse, cross-stratified feldspathic sandstones, siltstones, conglomerates, dark blue marly mudstones, tuffs and oolitic limestones (Voisey and Williams, 1964, p. 68).

Member: Rangari Limestone (Voisey and Williams, 1964).

Synonymy: Rangari Limestone Member, Campbell and Engel, 1963; Voisey and Williams, 1964, p. 68; White, 1964a, c; Voisey, 1964; Manser, 1965; Jenkins, 1969 (in part); Moore and Roberts, 1976.

Type Locality: Beside the Manilla-Boggabri road 1.7 km east of 'Rangari' at 30°40.3′ S 150° 23.3′ E, designated by Voisey and Williams (1964).

Thickness: 5 m in the type locality thinning southwards, not reaching the type section of the Tulcumba Sandstone in Swains Gully.

Lithologies: Oolitic limestone with minor bioclastic (crinoidal) limestone and limestone conglomerate.

Age: The conodonts *Siphonodella crenulata* and *S.* sp. cf. *S. isosticha* recovered from the Rangari at 'Carrol Gap' (by G. M. Philip, pers. comm.) indicate a mid-Tournaisian age.

General Comments:

The Tulcumba Sandstone crops out on the western limbs of the Werrie and Belvue Synclines over a distance of 58 km from south of 'Merlewood' north to 'Rangari'. It can also be questionably identified to the east of the synclinal axes over a distance of 13 km at and between the Namoi and Peel Rivers (see Fig. 5). On the western limbs the Tulcumba disconformably overlies Devonian units while to the east the ?Tulcumba Sandstone conformably overlies the Mandowa Mudstone (see Fig. 4).

Age: The basal Carboniferous age of the Tulcumba Sandstone was first established by Campbell and Engel (1963) who not only recognized Carboniferous fossils in this unit but also the Devonian lycopod *Leptophloem australe* in the underlying unit.

Brachiopods from the Rangari Limestone and the base of the overlying Namoi Formation at 'Rangari' have been assigned to the *Spirifer sol* and *Schellwienella* cf. *burlingtonensis* Zones respectively and assigned a mid-Tournaisian age (Roberts, 1975). Conodont evidence is in agreement with such an age determination.

Luton Formation (McKelvey and White, 1964)

Synonymy: ?Barraba Series (in part), Benson, 1913a, pl. XX.
?Barraba Mudstones (in part), Benson, 1917b, pl. XIX.
Luton Formation, McKelvey and White, 1964; White, 1965 (in part); McKelvey, 1968.

Type Section: Extends from a point southeast of 'Luton' at G.R. 232 164 (base) (Bangheet, 1:100,000 Geol. Series) northwest to Dry Creek, then downstream to the junction with Pallal Creek and then downstream to the Pallal — Bingara road at G.R. 214 177 (top), (McKelvey and White, 1964; McKelvey, 1968).

Thickness: 560 m in the type section thinning southwards to 340 m near 'Bereen', > 340 m at Slaty Gully, 'Burindi' and 220 m to the northwest at Mount Jerrybang.

Lithologies: Calcareous or arkosic sandstones and siltstones interbedded with thick mudstone sequences, rare limestone and conglomerate (McKelvey and White, 1964).

Discussion: The Luton Formation generally rests conformably on the underlying Mandowa Mudstone; an exception to this rule is the section exposed at Mount Jerrybang (see Fig. 4). The upper contact of the Luton Formation is conformable with the overlying Namoi Formation.

While the Luton Formation encompasses a wide variety of lithologies it is distinguished in the field primarily by the presence of relatively thick sandstone beds which are rare in the underlying Mandowa Mudstone and the overlying Namoi Formation. As most sandstone beds within the Luton are generally less than 6 m thick and as no sequence of beds or single sandstone bed can be recognized in more than one section it seems that the majority of sandstone beds are lenticular. Unfortunately even the thickest sandstone beds are difficult to trace for any great distance due to paucity of outcrop. In short sections with very few sandstone beds it can be difficult, if not impossible, to decide which of the early Carboniferous stratigraphic units is represented.

Near 'Bereen' the Luton Formation is defined by calcareous sandstones at the base and a conglomerate at its upper limit (Hill, 1973). The conglomerate lenses out to the north and two sections west of 'Bereen' are known thereabouts in which no coarse lithologies are present to distinguish the upper limit of the Luton. However sandstone and conglomerate beds north and south of these sections approximately define the position of the Luton/Namoi contact.

Five km south of 'Bereen' a submarine channel approximately 100 m deep and at least 0.6 km wide cuts through mudstones of the Luton Formation (Crook and Powell, 1976). The channel is filled with rhythmically-bedded feldspathic sandstones, siltstones, mudstones and has conglomerate at the base.

Variation in the Luton Formation is such that the only sections to show overall similarities to the type section are those between the Elcombe and Peel Faults south from Warialda (McKelvey, 1967). In those sections thick homogeneous coarse sandstones often with erosive lower contacts (proximal turbidites) are not uncommon but are usually less than 3 m thick with mudstone and siltstone dominating to the extent that coarser lithologies are often excluded in sections up to 100 m thick. Since sandstone beds which characterize the Luton Formation are lenticular and often rare it could be expected that both the upper and lower contacts of the Luton Formation are somewhat diachronous. The variation in lithology between sections assigned to the Luton, and the distance between well-exposed sections (up to 30 km), between which outcrop is minimal, are such that some doubt exists as to the validity of this formation as a mappable unit away from the type area.

Age: Campbell and McKellar (1969) reported the early Tournaisian *Tulcumbella tenuistriata* Zone from the Luton Formation. Subsequently Roberts (1975) gave the location of the fauna as the base of the Luton Formation in the type section. Roberts (1975) also reported brachiopods from the Luton Formation at Mount Jerrybang showing an affinity with the late Tournaisian *Schellwienella* cf. *burlingtonensis* Zone. To date no other macrofaunal localities within the Luton have been described.

Below the type section of the Luton Formation fragments of *Siphonodella* sp. have been recovered at the top of the Mandowa Mudstone whereas to the south at 'Bereen', *Dollymae* sp. has been recovered 14 m below the Luton (see Fig. 4). This genus has previously been reported only from Tournaisian conodont zones younger than those with *Siphonodella*. Where conodonts have been recovered elsewhere, it appears that the base of the Luton is Carboniferous although faunas are sparse and cannot be assigned to specific zones.

In the type section *Dollymae hassi* has been recovered 50 m below the top of the Luton Formation. This species has a short range in Belgium but as associated gnathodids in N.S.W. are rare, it cannot here be confidently assigned to a narrower range than the *Gnathodus punctatus, G. semiglaber* and *G.* sp. *A.* Zones of Jenkins (1974). A fauna from the *anchoralis* Zone occurs at the top of the Luton Formation near 'Claremont' 10 km NE of Gravesend, whereas at Mount Jerrybang 10 km SSW of Gravesend conodonts from limestone blocks in a conglomerate close to the top of the Luton have yielded a fauna from the *G. semiglaber* Zone.

NAMOI FORMATION (Voisey and Williams, 1964)

Synonymy: Burindi Series (in part), Benson, 1913-1920; Lloyd, 1933, p. 91; Carey, 1937.
Lower Burindi Series (in part), Carey and Browne, 1938.
Burindi Group (in part), Voisey, 1958; Chappell, 1961.
Namoi Formation, Campbell and Engel, 1963; Voisey and Williams, 1964, pp. 69-70; McKelvey and White, 1964; Voisey, 1964; White, 1965; Manser, 1965; McKelvey, 1968; Roberts, 1975; Moore and Roberts, 1976.
Namoi Formation (= Goonoo Goonoo Mudstone south of Peel River on east limb of Werrie Syncline), White, 1964a, b, c.

Type Section: Swains Gully from 30° 02.2′ S 150° 33.6′ E (base) to 30° 02.3′ S 150° 34.5′ E (top) (designated by Voisey and Williams, 1964). Benson (1917a, p. 265) gave the 'type locality' of the Burindi 'Mudstones' as 'near Portion 106, Parish of Burindi'. This locality (near the upper limit of Hellholes Creek west of 'Burindi') corresponds to the upper part of the Namoi Formation but is cut by a major NNW trending fault (White, 1965).

Thickness: 690 m in the type section (Voisey and Williams, 1964), approximately 500 m on the west side of the Belvue Syncline near Keepit Dam. Due to structural complications the thickness of the Namoi can be determined only approximately north

of Keepit. In Slaty Gully near Caroda the Namoi is more than 1000 m thick while near Mount Jerrybang it is approximately 1,200 m thick.
Lithologies: Olive-green to olive-brown siltstones and mudstones with rare sandstones, limestones, conglomerate and pebbly sandstone.

Member: Pallal Conglomerate (McKelvey, 1968).
Synonymy: Pallal Conglomerate Member, McKelvey, 1968.
Type Section: No section was specifically designated as the type by McKelvey (1968) but he mentions only one section near 'Pallal' (at G.R. 203 164 Bangheet, 1:100,000 Geol. Series) which is here taken to be the type section.
Thickness: Up to 66 m.
Lithologies: Cross-bedded coarse sandstone, lensoidal conglomerate and siltstone.
Age: An age has not yet been determined from within this unit but its stratigraphic position, approximately 300 m below a fauna with *Polygnathus bischoffi* and well above a fauna with *Dollymae hassi,* suggests assignment to the *anchoralis* Zone.

General Comments:

The Namoi Formation is the most persistently outcropping unit in the Tamworth Belt. It can be recognized from 'Royston' south of Swains Gully to Gravesend, a distance of 180 km. The Namoi has a conformable contact with the underlying Tulcumba Sandstone between 'Royston' and 'Rangari' and with the Luton Formation north from 'Burindi'. Between 'Rangari' and 'Burindi' the Namoi Formation cannot be lithologically distinguished from older mudstones and siltstones.

The upper contact of the Namoi with the Merlewood and Caroda Formations varies from gradational to erosional. Erosional contacts have been reported from the western limb of the Werrie Syncline south of 'Merlewood' (Moore and Roberts, 1976) and the eastern limb (Crook *in* Campbell, 1969). West of 'Burindi' several sections offering good exposure of this boundary show a variation from gradational to abrupt contacts and suggest that the erosional contacts cannot represent major breaks in sedimentation.

Generally the Namoi Formation consists of a monotonous sequence of olive-green to olive-brown fossiliferous and unfossiliferous fine siltstones and mudstones with minor sandstone beds. However, unnamed coarse polymictic orthoconglomerates with well-rounded pebbles cut through these fine-grained sediments in a number of sections. These conglomerates are lenticular and are restricted in distribution to small areas near 'Rangari' and the type section; away from these areas conglomerate is rarely found in this unit.

Age: Roberts (1975, p. 8) designated the Swains Gully Section as the reference section of the *Spirifer sol* and *Schellwienella* cf. *burlingtonensis* brachiopod Zones. He thus assigns a mid to late Tournaisian age to the Namoi Formation. Conodont evidence for the age of the top of the underlying formations and the base of the Namoi Formation has been discussed previously (see Luton Formation and Tulcumba Sandstone herein).

At the top of the Namoi Formation conodonts from the *S. anchoralis* Zone have been recovered in the type area. Near 'Burybury' (west of Barraba) *Doliognathus latus* and *Gnathodus* sp. nov. (characterized by a parapet on the inner side ornamented with transverse ridges and a smooth outer platform) has been recovered at this level 100 m above a fauna typical of the *S. anchoralis* Zone. This fauna is younger than those with *S. anchoralis* but as it is not present in either the type Tournaisian or the type Visean in Belgium it is difficult to assign this fauna to either series. Further north near 'Luton' *Polygnathus bischoffi* and *Patrognathus* sp. have been recovered near the top of the Namoi while near Mount Jerrybang *P. bischoffi* occurs with *Mestognathus beckmanni* suggesting an early Visean age.

MERLEWOOD FORMATION (Voisey and Williams, 1964)

Synonymy: Kuttung Series (in part I), Benson, Dun and Browne, 1920.
Lower Kuttung Series, Carey, 1937.
Lower Kuttung Group, Crook, 1961.
Merlewood Formation, Voisey and Williams, 1964, p. 70; White, 1964a; Voisey, 1964; Manser, 1965; Roberts, 1975; Moore and Roberts, 1976.

Type Section: Voisey and Williams (1964) designated the Merlewood section of Carey (1937, p. 351) as the type. This section runs almost east-west close to the junction of Portions 9 and 61, Parish of Babinboon in an unnamed tributary of Swains Gully immediately north of 'Merlewood' at 31°3′ S, 150°34.5′ E.

Thickness: 1,300 m in the type section:

Lithologies: Coarse, pink to buff lithic sandstone, commonly cross stratified with scour and fill structures, lensoidal polymictic conglomerate, magnetite sandstone, silty mudstone and pyroxene andesite flows.

Members: Voisey and Williams (1964, pp. 70-71) named six members within the Merlewood Formation. These had all been previously recognized by Carey (1937) who described them using informal names. Of these members the Hill 60 Member is the only one which has received subsequent recognition. That member has since been incorporated into the Kyndalyn Mudstone Member (Moore and Roberts, 1976).

KYNDALYN MUDSTONE MEMBER (Moore and Roberts, 1976)

Synonymy: Oolitic grits and conglomerates, Carey, 1937.
Hill 60 Member, Voisey and Williams, 1964; White, 1964b; Roberts, 1975.
Kyndalyn Mudstone Member, Moore and Roberts, 1976.

Type Section: Donnellys Springs Creek from G.R. 591 594 to G.R. 595 595 (Winton, 9035-IV-N, 2 inches/mile) (Moore and Roberts, 1976).

Thickness: 170 m in the type section, thinning away from this section.

Lithologies: Interbedded mudstone, siltstone and minor lithic sandstone in the type section with oolitic limestone, oolitic limestone conglomerate and polymictic conglomerate also present away from the type section (Moore and Roberts, 1976).

The Merlewood Formation has been recognized in the Belvue Syncline 40 km north of the type section and southwards as far as the northern edge of the Liverpool Ranges

75 km to the south. This formation generally has a gradational lower contact but a local erosional contact with the Goonoo Goonoo Mudstone has been reported by Crook (*in* Campbell, 1969) and with the Namoi Formation by Moore and Roberts (1976).

The Coepolly Conglomerate, Voisey and Williams (1964), abruptly overlies the Merlewood Formation. Jones *et al.* (1973) show a break in sedimentation at this level based on the correlation of the Coepolly Conglomerate with the Spion Kop Conglomerate (McKelvey and White, 1964).

Age: Marine fossils have so far been found only in the Kyndalyn Mudstone Member. Based on the occurrence of brachiopods from the *Gigantoproductus tenuirugosus* Subzone of the *Delepinea aspinosa* Zone of Roberts (1975), Jones and Roberts (1976) assigned a middle Late Visean (V3b) age to this level. Only two conodont species have been recovered from this unit (*Patrognathus* sp. and *Rhachistognathus* cf. *muricatus*). Although both species are present in oolitic limestones in the Caroda Formation to the north the ranges of these species are not sufficiently well established to suggest a correlation between the fossiliferous layers based on conodont evidence.

CARODA FORMATION (McKelvey and White, 1964)

Synonymy: Rocky Creek Series (in part), Benson, 1913-1917.
Caroda Formation, McKelvey and White, 1964; White, 1965; McKelvey, 1967; McKelvey, 1968.

Type Section: No location for the type section has been published. The name derives from Caroda Post Office west of Bingara, and the sections in that vicinity are meant to make up the type (McKelvey, 1967). While the section (east and west from the bridge over the Horton River) is folded and faulted, it is possible to put together a composite section due to the repetition of a persistent oolitic limestone horizon.

Thickness: About 650 m around Caroda Post Office, appears to maintain this thickness along strike although most sections are structurally complex. On the western limb of the Rocky Creek Syncline a complete section 320 m thick is found in the vicinity of 'West Lynne'.

Lithologies: Cross-bedded sandstones, lenticular orthoconglomerates with minor cross-bedded oolitic limestone and calcareous and magnetite sandstones.

Comments: The Caroda Formation crops out over a distance of 120 km from 5 km north of 'Rangari' to Gravesend. It is lithologically very similar to, and appears to be an approximate time-equivalent of the Merlewood Formation. The Caroda Formation conformably overlies the Namoi Formation, although often abruptly, and is disconformably overlain by the Spion Kop Conglomerate (White, 1965). The Caroda Formation contains paralic and terrestrial sandstone and conglomerate at the base overlain by marine sediments, chiefly sandstone and limestone, which are in turn abruptly overlain by fluvial sandstone, conglomerate and shale. Locally thin dirty coal seams and purple shales (up to 3 m thick) are developed in the uppermost and lowermost parts of the Caroda.

Age: Roberts (1975) indicates that at least part of the Caroda Formation lies within the *Gigantoproductus tenuirugosus* Subzone of the *Delepinea aspinosa* Zone (as does the Kyndalyn Mudstone Member). The location of the fossils used for this age determination is most probably the oolitic limestone next to the bridge over the Horton River near Caroda Post Office. Roberts correlates this zone with the middle portion of the upper Visean of Belgium (i.e. V3b). Conodonts recovered from this level include *Mestognathus bipluti, Gnathodus girtyi collinsoni* and *Cavusgnathus* sp. and suggest a Late Visean (V3c) age.

CROW MOUNTAIN CREEK BEDS (Price, 1973)

Synonymy: Burindi Series (in part), Benson, 1913-1917.
Burindi Group (in part), Voisey, 1958; Chappell, 1961.
Crow Mountain Creek Beds, Price, 1973, p. 204.

Type Section: A type section has not been designated due to relatively intense deformation although a representative section through the unit was described at Crow Mountain Creek (Price, 1973, p. 205).

Thickness: A thickness cannot be determined for this unit due to the intense deformation.

Lithologies: Basal massive mudstones with conglomerate, sandstone, siltstone and limestone; in the upper part, sandstone, conglomerate, siliceous mudstone and pyroclastics.

Comments: This unit has been subdivided into two units by Simandjuntak (1977). The basal unit has marine fossils and conglomerate with a volcanic clastic assemblage. The upper unit appears to be non-marine with conglomerates containing abundant clasts of radiolarian jasper derived from the Woolomin beds to the east (Price, 1973). Although Simandjuntak's two units appear to be conformable, their original relationship to the surrounding rocks cannot be determined as they lie within a fault-bounded block.

Age: Brachiopods from the fossiliferous horizons, identified by K. S. W. Campbell (*in* Simandjuntak, 1977) indicate that the lower part of the Crow Mountain Creek Beds belongs to either the *Orthetes australis* or *Delepinea aspinosa* Zones. Rare isolated occurrences of *Gnathodus*? *reversus, Cavusgnathus* sp. and *Patrognathus* sp. suggest that this unit spans the interval from early to late Visean.

CORRELATION WITHIN THE NORTHERN TAMWORTH BELT

Correlation of the principal sections in the northern Tamworth Belt is indicated in Fig. 6. The correlation shown is based entirely on conodont faunas since brachiopod zones proposed by Roberts (1975) are either much broader, covering up to 6 conodont zones in the case of the *S.* cf. *burlingtonensis* Zone, or have a limited established distribution, as with the *T. tenuistriata* and *S. sol* Zones. Previous correlations within the Tamworth Belt (Jones *et al.,* 1973; Roberts, 1975, fig. 11 — refigured by Jones and Roberts 1976, fig. 3) have been based largely on brachiopod faunas with ammonoids and conodonts providing ages in terms of European stages. Correlations within the northern Tamworth Belt by these authors are largely restricted to the consideration of two composite sections which covered (1) the Werrie and Belvue Synclines and (2) the Rocky Creek Syncline. The former was composed of the Swains Gully and 'Rangari' sections while the latter referred to the type sections of the Luton and Caroda Formations (and the intervening Namoi Formation) near Caroda, with

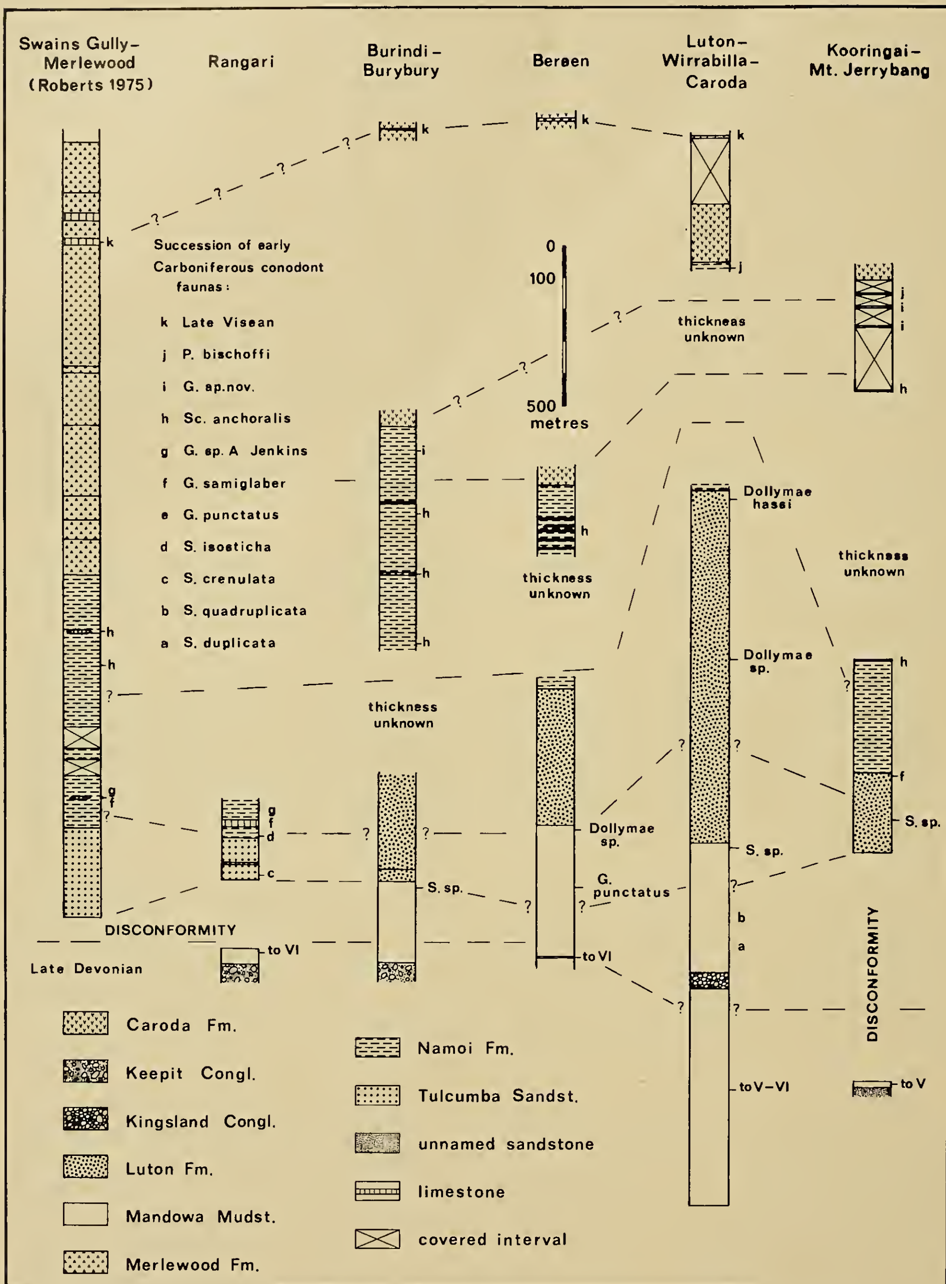

Fig. 6. Correlation of principal sections in the Early Carboniferous of the northern Tamworth Belt.

spot ages from 'Bereen' (Philip and Jackson, 1970) and Mount Jerrybang (Roberts, 1975). Although Roberts (1975) clarified a number of points concerning the correlation given by Jones *et al.* (1973), conodont and lithological evidence suggest the following additional modifications to the correlation offered by these authors:

(1) The Mandowa Mudstone ranges up into the Carboniferous on the eastern limbs of the Werrie, Belvue and Rocky Creek Synclines. The Wocklumerian age determined by Philip and Jackson (1970) is from a limestone in this unit rather than from the overlying Luton Formation (Hill, 1973; Gould, 1975, p. 455).

(2) There is little or no evidence for a break in sedimentation at the base of the Luton Formation except at Mount Jerrybang. Furthermore the Mandowa/Luton contact appears to be diachronous as indicated by the presence of *Dollymae* sp. at this level at 'Bereen' and *Siphonodella* sp. at 'Luton'.

(3) The top of the Luton Formation (and base of the overlying Namoi Formation) is diachronous as suggested by the presence of an *anchoralis* fauna at this level at 'Claremont', *G. semiglaber* at Mount Jerrybang and *Dollymae hassi* in the type section.

(4) The top of the Namoi Formation becomes younger to the north; the *anchoralis* Zone is found at this level south of 'Burybury' while younger faunas are found at 'Burybury' and to the north. A significant break in sedimentation at this level is unlikely as a gradational contact with the overlying Caroda and Merlewood Formations has been observed in a large number of sections.

Acknowledgements

I thank Dr T. B. H. Jenkins of the University of Sydney for his encouragement and helpful criticism throughout all stages of the preparation of this paper. I thank also the staff of the University of New England, in particular Dr B. McKelvey, for their co-operation and advice. The research was conducted during tenure of a Commonwealth Postgraduate Award at the Department of Geology and Geophysics, University of Sydney.

References

Benson, W. N., 1913a. — The geology and petrology of the Great Serpentine Belt of New South Wales. Part i, Introduction. *Proc. Linn. Soc. N.S.W.* 38: 490-517.

——, 1913b. The geology and petrology of the Great Serpentine Belt of New South Wales. Part ii, The geology of the Nundle district. *Proc. Linn. Soc. N.S.W.* 38: 569-596.

——, 1915a. — The geology and petrology of the Great Serpentine Belt of New South Wales. Part iv, The dolerites, spilites and keratophyres of the Nundle district. *Proc. Linn. Soc. N.S.W.* 39: 121-173.

——, 1915b. — The geology and petrology of the Great Serpentine Belt of New South Wales. Part v, The geology of the Tamworth district. *Proc. Linn. Soc. N.S.W.* 40: 540-624.

——, 1917a. — The geology and petrology of the Great Serpentine Belt of New South Wales. Part vi, A general account of the geology and physiography of the western slopes of New England. *Proc. Linn. Soc. N.S.W.* 42: 223-245, 250-280.

——, 1917b. — The geology and petrology of the Great Serpentine Belt of New South Wales. Appendix to part vi, The Attunga district. *Proc. Linn. Soc. N.S.W.,* 42: 693-700.

——, 1918a. — The geology and petrology of the Great Serpentine Belt of New South Wales. Part vii, The geology of the Loomberah district and a portion of the Goonoo Goonoo Estate. *Proc. Linn. Soc. N.S.W.* 42: 320-360, 363-384.

——, 1918b. — The geology and petrology of the Great Serpentine Belt of New South Wales. Part viii, The extension of the Great Serpentine Belt from the Nundle district to the coast. *Proc. Linn. Soc. N.S.W.* 43: 593-599,

——, Dun, W. S., and Browne, W. R., 1920. — The geology and petrology of the Great Serpentine Belt of New South Wales. Part ix, The geology, palaeontology and petrography of the Currabubula district, with notes on adjacent regions. Section A. General geology. *Proc. Linn. Soc. N.S.W.* 45: 285-317.

Campbell, K. S. W., 1969. — Carboniferous system. In Packham, G. H. (ed.) The geology of N.S.W. *J. geol. Soc. Aust.* 16 (1); 245-265.

——, and ENGEL, B., 1963. — The faunas of the Tournaisian Tulcumba Sandstone and its members in the Werrie and Belvue Synclines, N.S.W. *J. geol. Soc. Aust.* 10(1) : 55-122.

——, and MCKELLAR, R. G., 1969. — Eastern Australian Carboniferous invertebrates; sequence and affinities. *In* (pp. 77-119) CAMPBELL, K. S. W. (ed.) *Stratigraphy and Palaeontology: Essays in Honour of Dorothy Hill.* Canberra: ANU Press.

CAREY, S. W., 1934. — The geological structure of the Werrie Basin. *Proc. Linn. Soc. N.S.W.* 59: 351-374.

——, 1937. — The Carboniferous sequence in the Werrie Basin. *Proc. Linn. Soc. N.S.W.* 62: 341-376.

——, and BROWNE, W. R., 1938. — Review of the Carboniferous stratigraphy, tectonics and palaeogeography of New South Wales and Queensland. *J. Proc. R. Soc. N.S.W.* 71: 591-614.

CAWOOD, P. A., 1976. — Cambro-Ordovician strata in northern New South Wales. *Search* 7(7) : 317-318.

CHAPPELL, B. W., 1958. — The geology of the Wean-Maules Creek — Borah Creek area (between Manilla and Boggabri, N.S.W.). Armidale: University of New England, B.Sc. (Hons) thesis, unpubl.

——, 1961a. — Manilla-Moore Creek district, N.S.W., and petrology of greywackes of Baldwin Formation. Armidale: University of New England, M.Sc. thesis, unpubl.

——, 1961b. — Stratigraphy and structural geology of the Manilla-Moore Creek district, N.S.W. *J. Proc. R. Soc. N.S.W.* 95: 63-75.

CLARKE, W. B., 1852. — Report on the general geological character of the country between Marulan and the Peel River (report no 1). *Votes & Proc. Legislative Council N.S.W.* 1: 463-467.

——, 1853a. — Report on the geology of the Clarence district and the adjoining regions. *Votes & Proc. Legislative Council N.S.W.* 2:373-385.

——, 1853b. — Report on the geological structure of the western slopes of the highlands of New England, between the summits of the cordillera and the interior, in the basins of the Gwydir and Macintyre Rivers. *Votes & Proc. Legislative Council N.S.W.* 1: 597-614.

CROOK, K. A. W., 1958. — Geological evolution of Tamworth Trough. Armidale: University of New England, Ph.D. thesis, unpubl.

——, 1961. — Stratigraphy of the Parry Group (Upper Devonian-Lower Carboniferous), Tamworth — Nundle district, N.S.W. *J. Proc. R. Soc. N.S.W.* 94: 189-207.

——, 1964. — Depositional environments and provenance of Devonian and Carboniferous sediments in the Tamworth Trough, N.S.W. *J. Proc. R. Soc. N.S.W.* 97(1) : 41-53.

——, and POWELL, C. McA., 1976. — The Tamworth Trough: some problems in the evolution of an arc-trench gap. In *The evolution of the southeastern part of the Tasman Geosyncline. Excursion Guide 17A. 25th I.G.C.* (pp. 101-122). Canberra: Progress Press.

De KONINCK, L. G., 1876. — Description of the Palaeozoic fossils of New South Wales. *Mem. Soc. Roy. Liege* 2(2) (in French). Translation published in *Mem. geol. Surv. N.S.W.,* Pal. 6 (1898).

ENGEL, B. A., 1954. — The geology of the southwest portion of the county of Darling, N.S.W. Armidale: University of New England, B.Sc. (Hons) thesis, unpubl.

GOULD, R. E., 1975. — The succession of Australian pre-Tertiary megafossil floras. *Botanical Review* 41(4) : 453-483.

HARRINGTON, H. J., 1974. — The Tasman Geocyncline in Australia. In DENMEAD, A. K., TWEEDALE, G. W., and WILSON, A. F. (eds.). *The Tasman Geosyncline.* (pp. 383-407). Brisbane: Geol. Soc. Austr., Qld Div.

HILL, B. D., 1973. — Selected aspects of the Upper Devonian-Carboniferous sedimentation west of Barraba, N.S.W. Armidale: University of New England, B.Sc (Hons) thesis, unpubl.

JENKINS, T. B. H., 1969. — Devonian of the Keepit Inlier. In PACKHAM, G. H. (ed.). The geology of New South Wales. *J. geol. Soc. Aust.* 16: 242-243.

——, 1974. — Lower Carboniferous conodont biostratigraphy of New South Wales. *Palaeontology* 17(4) : 909-924.

JENSEN, H. I., 1907. — The geology of the Nandewar Mountains. *Proc. Linn. Soc. N.S.W.* 32(4) : 842-914.

JONES, P. J., CAMPBELL, K. S. W., and ROBERTS, J., 1973. — Correlation chart for the Carboniferous System of Australia. *Bull. Bur. Miner. Resourc. Geol. Geophys. Aust.* 156A.

——, and ROBERTS, J., 1976. — Some aspects of Carboniferous biostratigraphy in eastern Australia: a review. *B.M.R.J. Aust. Geol. Geophys.* 1: 141-151.

KASTNER, M., and SIEVER, R., 1979. — Low temperature feldspar in sedimentary rocks. *Am. J. Sci.* 279: 435-479.

KORSCH, R. J., 1977. — A framework for the Palaeozoic geology of the southern part of the New England Geosyncline. *J. geol. Soc. Aust.* 24(6) : 339-356.

LEITCH, E. C., 1974. — The geological development of the southern part of the New England Fold Belt. *J. geol. Soc. Aust.* 21(2) : 133-156.

LLOYD, A. C., 1933. — Preliminary report on the geological survey of the Gunnedah — Manilla district, with special reference to the occurrence of sub-surface water. *N.S.W. Dept. Mines Ann. Rep.* 89, 89-91.

MANSER, W., 1959. — The geology of the Curlewis-Gunnedah-Boggabri areas. Armidale: University of New England, MSc. (prelim.) thesis, unpubl.
———, 1965. *Geological map of New England 1:100,000 Gunnedah sheet no. 320 with marginal text.* Armidale: Univ. New England.
———, 1967. — Stratigraphic studies of the Upper Paleaozoic and post-Palaeozoic succession in the upper Hunter Valley. Armidale: Univ. New England, MSc. thesis, unpubl.
———, 1968. — *Geological map of New England 1:100,000 Wingen sheet no. 359 and parts of Macqueen (350), Barry (351) and Quirindi (360) with marginal text.* Armidale: Univ. New England.
McKELVEY, B. C., 1967. — Stratigraphy and petrology of a Devonian and Carboniferous sequence in north-eastern N.S.W. Armidale: University of New England. Ph.D. thesis, unpubl.
———, 1968. — *Geological map of New England 1:100,000 Bangheet sheet no. 280 with marginal text.* Armidale: Univ. New England.
———, 1974. — Devonian and Carboniferous sedimentation on the Tamworth Shelf. *Geol. Soc. Aust., Qld. Div., Field Conference Guide Book,* New England, 20-22.
———, and WHITE, A. H., 1964. — *Geological map of New England 1:100,000 Horton sheet no. 290, with marginal text.* Armidale: Univ. New England.
MOORE, D., and ROBERTS, J., 1976. — The Early Carboniferous marine transgression in the Merlewood Formation, Werrie Syncline, N.S.W. *J. Proc R. Soc. N.S.W.* 109: 49-58.
MORY, A. J., 1980. — The Early Carboniferous conodont biostratigraphy of the northern Tamworth Belt, N.S.W. Sydney: University of Sydney, Ph.D. thesis, unpubl.
PHILIP, G. M., and JACKSON, J. H., 1970. — Late Devonian conodonts from the Luton Formation, northern New South Wales. *Proc. Linn. Soc. N.S.W.* 91 (1) : 66-78.
PICKETT, J. W., 1960. — A clymeniid from the *Wocklumeria* Zone of New South Wales. *Palaeontology* 3 (2) : 237-241.
———, 1966. — Lower Carboniferous coral faunas from the New England district of N.S.W. *Mem. geol. Surv. N.S.W. Palaeont.* 15.
PITTMAN, E. F., 1881. — Report upon the Bingara and Ironbark Gold-Fields. *Ann. Rep. Dept. Mines N.S.W.*: 141-143.
POGSON, D. J., and HITCHINS, B. L., 1973. — *New England 1:500,000 geological sheet.* Sydney: Geol. Surv. N.S.W.
PRICE, I., 1973. — A new Permian and Upper Carboniferous (?) succession near Woodsreef, N.S.W. and its bearing on the palaeogeography of western New England. *Proc. Linn. Soc. N.S.W.* 97 (3) : 202-210.
ROBERTS, J., 1975. — Early Carboniferous brachiopod zones of Eastern Australia. *J. geol. Soc. Aust.* 22 (1) : 1-32.
——— , and OVERSBY, B., 1974. — The Lower Carboniferous geology of the Rouchel district, N.S.W. *Bull. Bur. Miner. Resourc. Geol. Geophys. Aust.* 147.
RUSSELL, T. G., 1979. — A re-appraisal of the Late Devonian Bective Unconformity, Tamworth Belt, north eastern N.S.W. *J. Proc. R. Soc. N.S.W.* 112: 63-69.
——— , 1980. — A clast fabric paleocurrent study of the Late Devonian Keepit Conglomerate, northeastern New South Wales. *J. Proc. R. Soc. N.S.W.* 113: 35-47.
SIMANDJUNTAK, T. O., 1977. — A study of Palaeozoic sedimentary succession in the Cobbadah district and its bearing on the evolution of the Tamworth Belt and the Peel Thrust. Armidale: University of New England, M. Sc. thesis, unpubl.
STONIER, G. A., 1891. — Progress report. *Ann. Rep. Dept. Mines N.S.W.*: 260-261.
——— , 1892. — Progress report. *Ann. Rep. Dept. Mines N.S.W.*: 125-137.
———, 1894a. — Progress report. *Ann. Rep. Dept. Mines N.S.W.*: 127-129.
———, 1894b. — Progress report. *Ann. Rep. Dept. Mines N.S.W.*: 131-137.
———, 1895a. — Geological report upon the Slaughter-house Creek district. *Ann. Rep. Dept. Mines N.S.W.*: 160-162.
———, 1895b. — Geological report on Crow Mountain. *Ann. Rep. Dept. Mines N.S.W.*: 167-171.
———, 1895c. — Report on country between Moree and Warialda. *Ann. Rep. Dept. Mines N.S.W.*: 171-172.
STUTCHBURY, S., 1853a. — Geological report. *Votes & Proc. Legislative Council N.S.W.* 2: 237-246.
———, 1853b. — Geological report. *Votes & Proc. Legislative Council N.S.W.* 2: 685-696.
VOISEY, A. H., 1934. — A preliminary account of the geology of the middle North Coast district of N.S.W. *Proc. Linn. Soc. N.S.W.* 59: 333-347.
———, 1936. — The Upper Palaeozoic rocks in the neighbourhood of Boorook and Drake, N.S.W. *Proc. Linn. Soc. N.S.W.* 61: 155-168.
———, 1938a. — The Upper Palaeozoic rocks in the neighbourhood of Taree, N.S.W. *Proc. Linn. Soc. N.S.W.* 63: 453-462.
———, 1938b. — The geology of the Armidale district. *Proc. Linn. Soc. N.S.W.* 63: 463-467.
———, 1939a. — The Upper Palaeozoic rocks between Mount George and Wingham, N.S.W. *Proc. Linn. Soc. N.S.W.* 64: 242-254.
———, 1939b. — The geology of the County of Buller, N.S.W. *Proc. Linn. Soc. N.S.W.* 64: 385-393.
———, 1939c. — The geology of the Lower Manning District of N.S.W. *Proc. Linn. Soc. N.S.W.* 64: 394-407.

——, 1940. — The Upper Palaeozoic rocks between the Manning and Karuah Rivers. *Proc. Linn. Soc. N.S.W.* 65: 192-210.

——, 1942. — The geology of the County of Sandon, N.S.W. *Proc. Linn. Soc. N.S.W.* 67: 288-293.

——, 1958. — The Manilla Syncline and associated faults. *J. Proc. R. Soc. N.S.W.* 91: 209-214.

——, 1959. — Tectonic evolution of north-eastern N.S.W., Australia. *J. Proc. R. Soc. N.S.W.* 92: 191-203.

——, 1964. — *Geological map of New England 1:100,000 Boggabri sheet no. 310 with marginal text.* Armidale: Univ. New England.

——, and WILLIAMS, K. L., 1964. — The geology of the Carroll-Keepit-Rangari area of N.S.W. *J. Proc. R. Soc. N.S.W.* 97 (1): 65-72.

WHITE, A. H., 1964a. — The stratigraphy and structure of the Upper Palaeozoic sediments of the Somerton-Attunga district, N.S.W. *Proc. Linn. Soc. N.S.W.* 89 (2): 203-217.

——, 1964b. — *Geological map of New England 1:100,000 Tamworth sheet no. 331 with marginal text.* Armidale: Univ. New England.

——, 1964c. — *Geological map of New England 1:100,000 Attunga sheet no. 321 with marginal text.* Armidale: Univ. New England.

——, 1965. — *Geological map of New England 1:100,000 Tareela sheet no. 300 with marginal text.* Armidale: Univ. New England.

——, 1966. — An analysis of Upper Devonian and Carboniferous sedimentation in part of the Western Foreland of the New England Eugeosyncline. Armidale: University of New England, Ph. D. thesis, unpubl.

WILLIAMS, K. L., 1954. — The geology of the Carrol-Wean area, N.S.W. Armidale: University of New England, B.Sc. (Hons) thesis, unpubl.